PART I - ADMINISTRATIVE

Section 1. General administrative information

Title of project

Numerical Study Of Flow-Field Structure On Salmonid Migration

BPA project number: 20068
Contract renewal date (mm/yyyy): ☐ **Multiple actions?**

Business name of agency, institution or organization requesting funding
University of Michigan, Ann Arbor, MI.

Business acronym (if appropriate) UMICH

Proposal contact person or principal investigator:

Name Prof. Ana I. Sirviente
Mailing Address Naval Architecture and Marine Engineering, 2600 Draper Road # 204 NAME
City, ST Zip Ann Arbor, MI 48109-2145
Phone 734-647-9411
Fax 734-936-8820
Email address asirv@engin.umich.edu

NPPC Program Measure Number(s) which this project addresses
Sections 5.0E, 5.0F, 5.2, 5.4.

FWS/NMFS Biological Opinion Number(s) which this project addresses
BO ID #s 4, 10, 13(g) among others.

Other planning document references

Short description
This proposal seeks to develop quantitative statistical correlations in-between the flow field information (obtained using a three-dimensional numerical model) and available salmonid out-migration trajectory data.

Target species
Salmonids. Analysis will be extended to other species at a later date.

Section 2. Sorting and evaluation

Subbasin
Mainstem

Evaluation Process Sort

CBFWA caucus	Special evaluation process	ISRP project type
Mark one or more caucus	If your project fits either of these processes, mark one or both	Mark one or more categories
☒ Anadromous fish ☐ Resident fish ☐ Wildlife	☐ Multi-year (milestone-based evaluation) ☐ Watershed project evaluation	☐ Watershed councils/model watersheds ☐ Information dissemination ☐ Operation & maintenance ☐ New construction ☒ Research & monitoring ☐ Implementation & management ☐ Wildlife habitat acquisitions

Section 3. Relationships to other Bonneville projects

Umbrella / sub-proposal relationships. List umbrella project first.

Project #	Project title/description

Other dependent or critically-related projects

Project #	Project title/description	Nature of relationship

Section 4. Objectives, tasks and schedules

Past accomplishments

Year	Accomplishment	Met biological objectives?

Objectives and tasks

Obj 1,2,3	Objective	Task a,b,c	Task
1	Develop/apply numerical model to select Columbia/Snake mainstem reaches	a	Data collection and evaluation
		b	Generate computational grid/s
		c	Run numerical model to obtain flow and turbulence field information
		d	Analyze data and store 3-D flow information in easily retrievable format
2	Obtain salmonid out-migration trajectories from existing data-bases	a	Evaluate existing data-bases and obtain most detailed and accurate information
3	Develop Statistical Models	a	As a first step, try using "black-box" non-linear regression analysis to develop correlations
		b	As the second/final step, develop neural network models and obtain refined correlations
4	Report results	a	Prepare final report and journal papers

Objective schedules and costs

Obj #	Start date mm/yyyy	End date mm/yyyy	Measureable biological objective(s)	Milestone	FY2000 Cost %
1	10/1999	4/2000	Measure 5.0E, 5.0F, 5.3, BO ID# 10, 13	-final 3-D flow & turbulence information for up to three reaches	55.00%
2	2/2000	4/2000	see above	- Obtain detailed fish trajectory information from available data-sets	10.00%
3	1/2000	7/2000	see above	- Develop correlations	25.00%
4	7/2000	9/2000	see above	- Prepare reports	10.00%
				Total	100.00%

Schedule constraints
None

Completion date
September 30, 2000

Section 5. Budget

FY99 project budget (BPA obligated):

FY2000 budget by line item

Item	Note	% of total	FY2000
Personnel	Salaries	%46	43,768
Fringe benefits		%14	13,568
Supplies, materials, non-expendable property	Computer usage/fax/phone related expenses etc	%0	100
Operations & maintenance		%0	0
Capital acquisitions or improvements (e.g. land, buildings, major equip.)		%4	4,000
NEPA costs		%0	0
Construction-related support		%0	0
PIT tags	# of tags:	%0	0
Travel	To BPA/workshops/conferences etc	%2	2,000
Indirect costs		%33	31,204
Subcontractor		%0	0
Other		%0	0
		TOTAL BPA FY2000 BUDGET REQUEST	$94,640

Cost sharing

Organization	Item or service provided	% total project cost (incl. BPA)	Amount ($)
		%0	
		%0	
		%0	
		%0	
		Total project cost (including BPA portion)	$94,640

Outyear costs

	FY2001	FY02	FY03	FY04
Total budget				

Section 6. References

Watershed?	Reference
☐	Sinha, S. K., F. Sotiropoulos, and A. J. Odgaard, (1998), "Three-dimensional numerical model for flows through natural rivers", Journal of Hydraulic Engineering, American Society of Civil Engineers, Vol. 124(1), 13-24.
☐	Cada, G. F., M. D. Deacon, S. V. Mitz, and M. S. Bevelhimer, (1997), "Effects of water velocity on the survival of downstream-migrating juvenile salmon and steelhead", Reviews in Fisheries Science, Vol. 5(2), 131-184.
☐	Hoar, W. S., (1954), "The behavior of juvenile Pacific salmon", Journal of the Fisheries Research Board of Canada, Vol. 11, 69-96.
☐	McDonald, J., (1960), "The behavior of Pacific salmon fry during their downstream migration", Journal of the Fisheries Research Board of Canada, Vol. 17, 655-676.
☐	Fangstam, H., I. Berglund, M. Sjoberg, and H. Lundqvist, (1993), "Effects of size and early sexual maturity on downstream migration during smolting in Baltic salmon", Journal of Fish Biology, Vol. 43, 517-529.
☐	Giorgi, A. E., and J. R. Stevenson, (1995), "A review of biological investigations describing smolt passage behavior at Portland district Corps of Engineers", Don Chapman Consultants, Boise, Idaho.
☐	Ransom, B. H., G. A. Raemhild, and T. W. Steig, (1988), Hydroacoustic evaluation of deep and shallow spill as a bypass mechanism for downstream migrating salmon and steelhead at Rock Island Dam, EPRI Report CS/EA/AP-5663-SR, Palo Alto, California.
☐	Ransom, B. H. and K. M. Malone, (1990), "Hydroacoustic evaluation of the sluiceways at Wanapum dam in passing juvenile salmon and steelhead trout during spring 1990", Hydroacoustic Technology Inc for Grant County PUD # 2, Ephrata, Washington.
☐	Coutant, C. C., and R. R. Whitney, (1998), "Fish behavior in relation to entrainment in hydropower turbines: A review", Transactions of American Fisheries Society, (press).
☐	Rutter, C., (1902), "Natural history of the quinnat salmon", Bulletin of the U.S. Fish Commission, Vol. 22, 65-142.
☐	Arnold, G. P., (1974), "Rheotropism in fishes", Biological review, Vol. 49, 515-576.
☐	Mundy, P. R., B. Watson, and R. Tuck, (1995), "Migratory behavior of juvenile spring chinook salmon in relation to water flow in the Yakima river", Washington.
☐	Raemchild, G. A., R. Nason, and S. Hayes, (1985), "Hydroacoustic studies of downstream migrating salmonids at hydropower dams: two case studies",

	Proceedings of the symposium on Small Hydropower and Fisheries, American Fisheries Society, Bethesda, MD.
☐	Biosonics, Inc., (1983), "Hydroacoustic assessment of downstream migrating salmon and steelhead at Wanapum and Priest Rapids dams in 1983", Public Utility District No. 2 of Grant County, Ephrata, WA.
☐	Sinha, S. K., (1997),"An algebraic grid generation scheme for three-dimensional natural river reaches", Communications in Numerical Methods in Engineering, John Wiley & Sons, New York, Vol. 13, 475-485.
☐	Babovic, V., and N. Bartoli, (1997), "An application of artificial neural networks in computational hydraulics", Environmental and Coastal Hydraulics: Protecting the Aquatic Habitat, 2:865-870.
☐	Boogaard, H. F. V., and A. C. H. Kruisbrink, (1996), "Hybrid modeling by integrating neural networks and numerical models", Hydroinformatics 96, Balkema, Rotterdam, 1996.
☐	Masters, T., (1993), "Practical neural network recipes in C++", Academic Press, New York.
☐	
☐	
☐	

PART II - NARRATIVE

Section 7. Abstract

An individual-based modeling approach focussing on the movement strategies of juvenile salmonid in response to three-dimensional velocity and turbulence variables is proposed. Existing field data for salmonid movement will be used to track fish-trajectories in three-dimensional space. Simultaneously a previously developed fully three-dimensional numerical model will be used to provide a comprehensive database of velocity and turbulence parameters. Finally, statistical correlations between fish-trajectories and local flow parameters will be formulated using advanced statistical modeling techniques such as nonlinear regression analysis and/or neural network modeling.

Such correlations are expected to have wide ranging impact in the understanding of salmonid out-migration behavior. The model may further be used to project fish population abundance through time to assess the risk that the population will fall below some threshold requiring mitigation. Finally, the quantitative information may be used to foster compatibility of engineered systems with the normal behavioral patterns of fish species leading to reduced mortality. These outcomes are directly aligned with the 1994 CBFWP and NMFS/USFWS 's goals.

Although not directly used in the context of the present study, the proposed numerical and statistical modeling techniques are technically sound and have been well

tested for several Columbia river reaches. The work will be completed in one year. Publication of the statistical correlations in respected refereed journal publications as well as periodic reports to the BPA would provide an easy means of result monitoring.

Section 8. Project description

a. Technical and/or scientific background

a.1 Introduction

Long term structural changes in fish population initiate as effect on individual fish. Cumulative individual effects, which include direct mortality and altered habitat suitability etc, lead to alterations in population density. Changes in population density are directly linked to previously overlooked non-biological factors such as three-dimensional flow field information, temperature, depth, etc. Despite this, to-date no empirical or mathematically quantifiable relationships currently exist which relate the movement of fish to changes in surrounding flow/turbulence field.

Until recently the complexity of a river flow field have remained unknown. Traditional methods to study river flows --such as field measurements and laboratory physical model studies-- are too expensive to undertake in details fine enough to provide insights into the physics of a highly three-dimensional flow. The geometrical complexities along with the changing upstream and downstream flow conditions induce very complex, three-dimensional turbulent shear flows which are characterized by secondary currents, vortex formation, flow reversal, turbulence anisotropy effects, etc.. Coupled with temporal variability, these are some of the reasons that result in difficulty in detailed data collection in the field at any instant of time.

A calibrated and well-formulated numerical model can greatly ease the study of affecting flow parameters and offers an attractive alternative for solving complex fluid mechanics problems encountered in practical engineering situations. However, up until today, although impressive, the progress in fully *three-dimensional* numerical modeling of flow through open channels had been such that the proposed schemes were not robust enough to be applied to a natural stream. Recently Sinha and colleagues (1998) proposed a method which is robust enough to be applied to natural river reaches of highly varying topography, and economical enough to be able to run on a work-station with minimal cost. This numerical model provides a good starting point for studies similar to the presently proposed work.

If three-dimensional flow field information is present, an attempt could be made to statistically correlate the trajectories of fish (single or a group of) with the local flow information. Statistical analysis could then be used to explore the possibilities of formulating a meaningful set of relations.

a.2 Background, history, and location of the problem

For the purposes of this proposal, we intend to limit our attention to juvenile salmon. In recent years, salmon populations of Pacific Northwest, a highly valued cultural and economic resource, have declined precipitously. Despite being one of the largest effort at ecosystem management undertaken to date in the United States, primarily aiming at balancing hydropower demands with salmon restoration activities, decline of salmon density in Pacific Northwest has been a hotly debated topic (Cada et al. 1997). Continued decline (although slower in the recent years) of salmon numbers in Columbia and Snake river systems indicates that present schemes and methodology require serious rethinking.

Clearly the information gathered by modeling salmon movement in natural water would be valuable. The immediate goal of this study is to assist in developing the ability to identify and assess key alternative hypotheses relating to Columbia/Snake River salmon ecosystem dynamics and to move towards stock recovery and rebuilding. The project will therefore provide tools to undertake a scientific ecosystem-based measure and reduce adverse environmental impacts on salmon. Any definitive quantitative movement pattern assessments may then be verified against the movement patterns of other fish species to ascertain a degree of overlap in its behavioral response.

Currently, we intend to focus our attention on several 3-4 mile long reaches in the *Columbia/Snake mainstem*. This would enable us to compare the behavioral patterns.

a.3 Literature review

Intensive research on salmonids, both basic and applied, has yielded important generalizations for understanding fish behavior. Among other issues, the behavior of juvenile salmonids in water flow, orientation of movements, flow cues to migration, and swimming speeds in different situations have occupied special attention by researchers (Hoar 1954; McDonald 1960; Fangstam et al. 1993; etc). A brief summary is presented in the following sections:

1. Vertical and horizontal distribution:

There is strong evidence that juvenile salmon migrating downstream are oriented to the upper portion of the water column (Giorgi and Stevenson 1995). One such evidence is available field data from upper portions of the water columns passing disproportionately higher density of fish. For example, in Columbia river, at Rock Island dam 87% of the fish passed through a shallow spill releasing only 50% of the discharge (Ranson et al. 1988). Similarly, at Wanapum dam, 4% of the fish passed through the sluiceway releasing only 0.5% of the discharge (Ransom and Malone 1990). Finally, in the forebay of Lower Granite dam on Snake river, 92% of the smolts were found to be in the upper 36 feet of the water column.

Despite strong propensity for juvenile salmonids to stay in the upper portions, concrete conclusions regarding the horizontal distribution of salmonids is not available.

It is likely that specific geometries of intakes and the river can be used to estimate the percentages of fish entrained in different portions of the cross-sections of the intakes.

Coutant and Whitney (1998) suggest adaptation of the salmonids in the upper portions of the water column is directly related to the riverine fluid dynamics. However, lack of research to establish the behavior of juvenile salmonids in water prevents any conclusive quantitative arguments about their predisposition.

2. Body orientation in flow:

Earliest studies indicated that juvenile salmon drifted downstream tail first keeping their heads upstream (Rutter 1902). Recent laboratory study of Nelson et al. (1994) supports this observation for chinook salmon underyearling migrants. Active swimming downstream was observed only in low velocities. Arnold (1974) pointed out that migration is a complex response to temporally and spatially varying flow fields, with a mix of passive and oriented movements.

Influence on speed and, possibly the orientation, of accelerating flows was observed by Mundy et al. (1995 draft). They found a strong correlation between episodic high movement rate of yearling chinook salmon past Prosser Dam on the Yakima river (Washington) and concurrent accelerations in flows. This is an important conclusion as it suggests that if the relatively quiescent waters of the reservoirs were replaced by accelerating velocities, it would lead to more active movement of the fish. However, the exact degree to which the movement is affected is not well known due to the lack of research as proposed in this study.

3. Effect of flow discharge:

A large number of field studies have been conducted to investigate the effect of stream flow on salmon movement. Direct observations of the number of fish migrating downstream and the amount of spill (release of water over spillways --rather than through turbines-- to help reduce mortality during peak migration season) are available (Raemchild et al. 1985, among many others). In general, a non-linear response was found between percentage of fish passed per percentage of river flow spilled. For example, at Wanapum dam in the Columbia river, night time spill of 20% of the instantaneous flow passed about 45% of the fish, while 50% spill passed only 60% of the fish (Biosonics 1983).

A detailed analysis was performed by McConnaha (1990) who correlated systemwide smolt survival data from 1970 through 1980 (except 1971) with the flow rate. His results indicate a simple exponential model might best describe the smolt mortality-flow rate relationship. He also cautioned that the data could contain significant errors and that other models elucidating relationships with other parameters should also be explored. Coutant and Whitney (1998) concluded that averaging over seasons and a fairly limited range of spill percentages obscured the underlying curvilinear response.

They also indicated that certain amounts of spill were likely to be more effective in passing fish than is indicated by the sheer bulk of flow.

It is clear from the above discussion that all of the studies mentioned above, a sample survey of fish behavioral studies, indicate a positive relationship between of flow discharge and salmonid migration. Because the previous studies were not undertaken to find the exact nature of flow rate-mortality dependence, most of these studies lack any definitive estimates. Furthermore, the estimates of mortality rate itself contained no information about any variances/errors and in fact can easily be shown to contain biases and errors in estimation (Cada et al. 1997).

a.4 Related work of key personnel

Please see our summarized resumes at the end of this proposal.

b. Rationale and significance to Regional Programs

There are two separate outcomes of this study. First, use of numerical modeling is a powerful tool to analyze flow physics and is expected to have a significant impact in traditional way to study stream flow problems. Secondly, the availability of statistical correlations would lead to insight into the movement strategies adopted by salmonids in its seaward out-migration. The significance of both these contributions is tremendous and would provide extended opportunities of the concept of integrated management with ecosystem functions at work to produce best field situations possible for anadromous salmonid seaward migration.

Proponents would like to further note that a previous version of this (unfortunately, unsuccessful) proposal submitted to the BPA for 1999 funding was categorized among ten innovative and technically acceptable proposals by the ISRP. ISRP acknowledged the strength of the idea and indicated that such proposals with novel ideas, at times initially spurned by the scientific/management establishment, may evolve into some of the most important mainstays of current practice.

Proponents hope that that both the CBFWA as well as the ISRP would recommend the present proposal in their effort to encourage innovative projects.

c. Relationships to other projects

A generic research proposal such as the one in this proposed study is relevant to a large number of on-going projects of wide ranging goals. Three such potential areas are outlined below.

The statistical correlations obtained as the final product of this research may directly be used in habitat restoration studies such as those being undertaken at Yakima fish protection and enhancement facilities (BPA # 9503300), Fort Hall reservation habitat enhancement (BPA # 92010000), Lake creek land acquisition and habitat restoration project (BPA # 9004401), among others.

Similarly, the information gathered may also be used to re-direct the salmonids away from the high nitrogen concentration areas (leading to gas bubble disease) and are therefore of interest to the following (few of the many) on-going projects: Gas bubble disease research and monitoring of juvenile salmonids (BPA # 9602100), Symptoms of GBD in salmon of the Columbia/Snake rivers (BPA # 9300802), and, Comparative survival rate study of hatchery pit tagged Chinook (BPA # 8712702).

Finally, projects such as those in which streamflow changes are proposed as means to reduce juvenile mortality rate may be better monitored/evaluated if the outcome of the proposed study is known. Among the many such on-going projects, two are Pacific Lamprey research and monitoring (BPA # 9402600), Hungry horse fisheries mitigation plan (BPA # 9101901).

d. Project history (for ongoing projects)

Not applicable. This is a new project.

e. Proposal objectives

The objectives of this project are itemized below:

- Solve for flow and turbulence field for several Columbia/Snake river mainstem. Generate an extensive three-dimensional data-base of these quantities.
- Obtain the fish trajectories through available field studies.
- Develop & apply neural network analysis to generate statistical correlations among the flow/turbulence field information with the fish movement data.
- Quantify the possible effects of increase in turbulence/secondary circulation levels in water and its effect on salmonid movement.
- Provide detailed data-bases for fully three-dimensional velocity and turbulence field information for the river reaches for future studies.

f. Methods

f.1. Numerical Modeling

To facilitate the modeling of three-dimensional flow structures in detail, the proposed work involves the application of a previously developed state-of-the-art numerical model (Sinha et al. 1998). The method solves the three-dimensional Reynolds-averaged Navier-Stokes (momentum as well as mass conservation) equations along with the standard $k-\varepsilon$ turbulence model formulated in generalized curvilinear coordinates. The model accounts directly for most large-scale roughness (boulders, rocks, etc.) using boundary-fitted coordinates along with a multi-block method for accurate resolution of the flow details around islands and other obstructions--note that classification of the roughness elements of a given reach as large- and small-scale is, obviously, defined relatively to the resolution of a particular computational mesh. Body-fitted computational meshes are generated algebraically using an efficient approach based on spline interpolation (Sinha 1997). Spatially varying small-scale roughness is accounted for by employing a generalized, two-point wall functions approach. An accurate and efficient procedure is developed for calibrating the roughness distribution in the numerical model with guidance from field and laboratory measurements. The water surface is treated as a sloping hard-lid whose shape is specified using field estimates.

The proponents of this proposal were recently involved in several similar projects downstream of Wanapum and Priest Rapids Dams in the Mid-Columbia river (Grant County Public Utility District). In one of these projects (downstream of Wanapum Dam), flow through a three-mile stretch of the Columbia River was numerically simulated to answer a variety of fish migration related issues (Sinha et al. 1998). The numerical model developed as a part of that study was calibrated and validated in detail against both field as well as experimental data. The fully three-dimensional flow features under the natural conditions were shown to be satisfactorily predicted. Since the model formulation was done in generalized curvilinear coordinates, it allows great flexibility to apply the model to a variety of other surface water systems. For example, the model was recently applied to two cooling ponds in central Illinois to address thermal stratification and its effect on indigenous fish in the lakes (Sinha et al. 1998).

f.2 Artificial neural network analysis

Simulated artificial neural networks (ANN) relate two or more sets of data (say, vertical and horizontal velocity components etc) to build a model that is able to learn a required function by being exposed to examples of the corresponding data patterns. The relationships between the patterns can be of arbitrarily complex mathematical order and, possibly, is the single most important reason for the increased utility of ANNs in engineering applications (Masters 1993).

ANNs may be used to model physical or biological systems very effectively. Their biggest advantage over traditional statistical techniques is that, even if the exact relationship between input and output data is unknown -but is acknowledged to exist, they can still be trained to learnt that relationship. The underlying physical processes (flow and turbulence field information, in the present context) may thus contain quantitative information without any single recognizable pattern. Babovic and Bartoli (1997) and Boogaard and Kruisbrink (1996) provide examples of two of the many successful engineering studies using ANNs.

f.3 Risks

The strength of the proposed method lies in its being completely mathematical and, therefore, it does not alter the environment in any fashion to affect humans or wild life. Decisions based upon such an analysis, however, have the potential to provide enhanced habitat for the fisheries at minimal cost and expenditure.

f.4 Critical hypotheses/Underlying assumptions

The level of grid refinement limits computer simulation of complex flows, such as those encountered in natural streams. The grid refinement restricts the size (or, alternatively, the resolution) of the problem. Depending upon the complexity of the river reach in concern, either a set of high density inter-connected models would be developed (previously done for Wanapum Dam tailrace reach, see sinha et al. 1998) or the resolution of the correlations would be reduced.

g. Facilities and equipment

The equipments needed to undertake this work are desktop workstations (for numerical modeling and data analysis). The University of Michigan maintains a vast array of desktop workstations and would provide the equipment needed to undertake this study.

h. Budget

Most of the grid generation and model development/analysis type work would be done by S. K. Sinha while A. I. Sirviente would provide expert support with the results of the project. As outlined in the time schedule, it is expected to result in full time involvement for a total of five and two months respectively. Salaries are computed accordingly. Direct and in-direct costs are computed according to the standard University of Michigan rates.

The only other expenses sought are those related to equipment such as computer time etc ($4,000) and support for travel ($3,000) to present the work at different meetings and forums of discussions.

Left over funds will be returned back to the agency.

Section 9. Key personnel

SUMMARIZED RESUME OF
Sanjiv Kumar Sinha

Education: Ph.D. (Civil Engineering), University of Iowa: 1996
M.S. (Civil Engineering), University of Minnesota: 1992
B.E.(Civil Engineering), University of Roorkee: 1989

Present Employment & Responsibilities: Assistant Professor (nontenure), Environmental and Water Resources Program, Department of Civil and Environmental Engineering, University of Michigan, Ann Arbor, MI 48109-2125. Tel: (734) 647-1747; Fax: (734) 763-2275; e-mail: sanjiv@engin.umich.edu

Sanjiv is a faculty of the Engineering College at the University of Michigan. His responsibilities include teaching two to three semester courses every year to undergraduate and graduate students in Civil Engineering; and, leading research efforts related to salmonid migration and Numerical Modeling at the University of Michigan. He has over six years of experience working on various fisheries and numerical modeling related issues (such as effective construction of fish bypass downstream of Wanapum dam, studying the effectiveness of Wells dam fish bypass structure, developing three-dimensional numerical models to predict flow features in Priest Rapids and Wanapum dam tailraces etc) on several reaches in the Columbia/Snake river system. His work has been published in a variety of rigorously refereed journals; and, along with serving as a reviewer for over half a dozen journals (such as Transactions of the American Fisheries Society, Journal of Irrigation and Drainage Engineering, Journal of Hydraulic Engineering, Journal of Cold Regions Engineering, and Water Resources Research), he also serves as a book editor for John Wiley and Sons Publishers.

Expertise: Areas of expertise include Computational fluid dynamics; Juvenile salmonid seaward-migration and smoltification; Environmental hydraulics; Biological processes in aquatic environment; River mechanics/Sediment transport.

Recent Publications:

Sinha, S. K., L. J. Weber, and A. J. Odgaard, "Numerical evaluation of fish bypass outfall alternatives", **Hydro-review**, North American Hydropower Industry Association, (in press).

Sinha, S. K., F. Sotiropoulos, and A. J. Odgaard, "Three-dimensional numerical model for flows through natural rivers", **Journal of Hydraulic Engineering**, American Society of Civil Engineers, Vol. 124(1), 1-12, January 1998.

Sinha, S. K., "An algebraic grid generation scheme for three-dimensional natural river reaches", **Communications in Numerical Methods in Engineering**, John Wiley & Sons, New York, John Wiley & Sons, New York, Vol. 13, 475-485, May 1997.

Marelius, F., and S. K. Sinha, "Experimental evaluation of flow past submerged vanes at high angle of attack", **Journal of Hydraulic Engineering**, American Society of Civil Engineers, Vol. 124(5), 542-545, May 1998.

Sinha, S. K., and G. Parker, "Causes of concavity in longitudinal river profiles", **Water Resources Research**, American Geophysical Union, Vol. 32, No. 5, 1417-1428, May 1996.

Past Collaborators:

G. Parker (U-Minnesota), A. J. Odgaard (U-Iowa), C. Paola (U-Minnesota), J. Southard (MIT), P. Wilcock (Johns Hopkins), L. J. Weber (U-Iowa), F. Sotiropoulos (Georgia-Tech), F. Marelius (RIT-Sweden), R. E. Ettema (U-Iowa), R. Seal (Waterways Experiment Station), R. E. Elder (Retired - formerly with Bechtel Corp.), V. C. Patel (U-Iowa), M. Dyer (Ameren Corp.), F. M. Holly (U-Iowa).

SUMMARIZED RESUME
ANA ISABEL SIRVIENTE, Ph.D.

Current Employment:

Assistant Professor,The University of Michigan, Naval Architecture and Marine Engineering Department, 2600 Draper Road; 204 NAME, Ann Arbor, MI 48109-2145. [Tel: (734)-647-9411; Fax: (734)-936-8820; e_mail: asirv@engin.umich.edu].

Research Interests:

Viscous Flow; Turbulent Flows; Computational Fluid Dynamics; Environmental Fluid Dynamics

Education:	Ph.D. (Mechanical Engineering), University of Iowa:	1996
	M.S. (Mechanical Engineering), University of Iowa:	1991
	B.E.(Naval Architecture), Polytechnic University:	1990

Scientific and Professional Organizations:

- Member, American Society of Mechanical Engineers
- Member of ASME-AMD Fluid Dynamics Technical Committee
- Associate Member, Society of Naval Architects and Marine Engineers
- Member of SNAME-Panel 11 Technical Committee
- Member, American Society of Engineering Education
- Member, American Institute of Aeronautics and Astronautics
- Associate Member of AIAA Fluid Dynamics Technical Committee

Current Responsibilities:

- Teaching two-three courses per year to undergraduate and graduate students (NAME 270: Marine Design; NAME 320: Marine Hydrodynamics I; NAME 321: Marine Hydrodynamics II; NAME 590: Computational Fluid Dynamics in Ship Design).
- Leading research efforts on experimental and numerical viscous and turbulent flows:
    • Enhancement of turbulence closures applied to resolve free-surface flows.
    • Further development of a numerical RANS-solver in conjunction with a Reynolds-Stress near wall turbulence closure.
    • Numerical and experimental study of the effects of polymer addition in the structure of turbulence.

Most Recent Journal Publications:

Sirviente, A.I. and Patel, V.C. (1998), "Experimentes in Momentumless Turbulent Wake of a Jet-Propelled Axisymmetric Body," **AIAA Journal**, (accepted).

Sirviente, A.I. and Patel, V.C. (1998), "Experiments in the Turbulent Near Wake of an Axisymmetric Body," **AIAA Journal**, (accepted).

Sirviente, A.I. and Patel, V.C. (1998), "Experiments in Momentumless Turbulent Wake of a Swirling Jet-Propelled Axisymmetric Body," **AIAA Journal** (submitted).

Parthsarathy, R., Sirviente, A.I. and Patel, V.C., (1993), "LDV Measurements in Separated Flow on an Elliptic Wing Mounted at an Angle of Attack on a Wall," Transactions of the ASME, **Journal of Fluids Engineering**, Vol. 116, pp. 258-264.

Section 10. Information/technology transfer

The technology transfer will be accomplished through oral presentation, technical reports to BPA, and journal publications. Managers will use the results of this study to evaluate the physical modifications at the dams and various management scenarios used to reduce salmonid mortality. The uncertainty associated with field data corresponding to fish movement will also be reduced. This will facilitate a review by state environmental agencies and determine the possibility of salmonid population reduction related waivers for the mainstem Columbia and Snake rivers. In addition, state and federal fisheries agencies, Indian tribes, and other interested parties will be able to quantitatively assess the effect of flow modifications on the downward fish migration and its resulting effect on the population density at any given time.

Congratulations!